REMARKABLE COMETS

A BRIEF SURVEY OF THE

MOST INTERESTING FACTS IN THE HISTORY

OF COMETARY ASTRONOMY

BY

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PREFACE.

THE scope of this little treatise is almost purely historical, it being intended as simply a handy work of reference to those comets which may be considered remarkable either for their brilliant appearance, their periodic returns, or for any other circumstance respecting them. The first edition was issued in January 1893; the second and third appeared early in 1894 and 1895 respectively; and in this, the fourth, the information is again carefully brought up to date. The author has been much gratified by the assurances he has received of the utility of the work.

W. T. L.

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REMARKABLE COMETS.

IT is not always possible to decide, from ancient and mediæval descriptions of unusual luminous appearances in the sky, whether they relate to comets, meteors, temporary stars, or peculiar atmospheric phenomena. We are indebted to Chinese annalists for most of the early accounts of comets, from which it has been possible, by their observed courses, to determine, with some probability, the nature of their orbits. But there is one exception. The earliest of all that come under this category was described by Aristotle, and appeared in the winter of B.C. 371, when he was only about thirteen years of age. As to the one which, according to Pliny, was seen at the time of the battle of Salamis (B.C. 480), it is impossible to say what it was. Nor can anything be ascertained respecting the path of a fine comet which is said to have been seen in B.C. 134, the year of the birth of Mithradates, the famous king of Pontus.

The word comet is derived, through the Latin *cometa* and the French *comète*, from the Greek κομήτης. In that language κόμη signifies the hair of the head, and the first idea of comets was that they were bodies with hair-like appendages, appearing to stream from them like the hair from a person's head. In later times these were called their tails, a designation still retained, though long since known to be a misnomer, for when the motions of comets were studied, it was found that the so-called tails as often preceded as followed them. The general direction of these appendages is opposite to that in which the Sun is situated with respect to the comet, but curved by the simultaneous motion of the comet, which is very rapid when near the Sun. After the invention of telescopes, and their application to astronomical observations, a number of very faint comets were discovered, many of which had no appearance of a tail, but simply consisted of nebulous-looking matter, and this indeed is the appearance presented even by large comets whilst still at a great distance from the Sun, the tail being developed as they approach him, and attaining its greatest size soon after the comet has passed perihelion, as the nearest point of its orbit to

the Sun is called. Many comets have, in addition to the usual curved tail, a fainter one nearly straight, probably consisting of matter shot forth with greater velocity; and there are cases on record of some with multiple tails.

Comets were a great puzzle in the early ages of the world, before astronomy became a science. They were also a great source of terror, and it is very probable that when the prophet Jeremiah exhorts the Israelites not to be "dismayed at the signs of heaven," as the heathen were (Jer. x. 2), he is referring to the appearance of a comet. The motions of these bodies were not understood until Newton applied to one of them, which appeared in the year 1680, his great principle of universal gravitation, and showed that it moved in an elliptic orbit round the Sun, but an ellipse much more elongated or eccentric than those of the planets. To him therefore is justly applicable the expression of the poet:—

"He, first of men, with awful wing pursued
The comet through the long elliptic curve,
As round innum'rous worlds he wound his way;
Till, to the forehead of our ev'ning sky
Returned, the blazing wonder glares anew
And o'er the trembling nations shakes dismay."

Having proved elliptic motion in the case

of one comet, he conjectured similar motion in those of others. Hence it was natural to infer that some at least of the comets moving in elliptic orbits would return to view, after having revolved through the whole circuit of these. But he was also aware that, in accordance with his principles, some of the comets might move in a conic section other than an ellipse—a parabola or even a branch of an hyperbola—and that such would not return at all. Halley undertook to calculate, on Newton's principles, the orbits of all the comets which had in his time been sufficiently observed to enable this to be done. He found one case (to be mentioned further on) in which the identity of comets observed in different years was possible (so that they might be the same comet seen at two returns to our parts of space), and another in which one had been seen three or more times, respecting which he felt so certain that these were appearances of the same body, that he ventured confidently to predict that it would return after his death. The conjecture that the comet of which the motions were calculated by Newton had been seen during previous returns, at very long intervals apart, was not founded upon any comparison of their orbits

(for none such could be calculated), but merely upon the near equality of the intervals, and is now known not to be consistent with a more rigid examination. But two returns of the one which Halley confidently predicted would return, have duly taken place. Since then many more of much shorter periods have been discovered. All these, however, are either telescopic or barely visible occasionally to the naked eye. The comets which have made the grandest appearances have been those which move either in parabolas or in ellipses so eccentric as to require several (often many) centuries for revolution through them.

From what precedes, it will be noticed that we do not stand on firm ground in dealing with the history of comets until we come to the time of Newton. The ancient philosopher Seneca, in a passage which has been often quoted, foretold that in some future age one would arise who should explain the motions of these bodies; but sixteen centuries rolled away before this prediction was fulfilled.

Tycho Brahé was the first to prove, by observations of the comet of 1577, and extending the conclusion by analogy to others, that they are not terrestrial phenomena, but

move in regions far beyond the limits of the earth's atmosphere, and even at distances greater than that of the Moon.

The earliest telescopic observations of comets were made in 1618—that most memorable astronomical year in which Kepler discovered his third law of the planetary movements, which led to Newton's discovery of the law of universal gravitation, and also the year in which the earliest record appears of an observation (by Cysat at Lucerne) of the great nebula in Orion. The splendid comet of 1680 was first seen with a telescope by Gottfried Kirch, at Coburg, in November; it is sometimes called Newton's comet, not so much because he observed it, as that in reference to it he showed the applicability of the law of gravitation to comets, and calculated its orbit upon that principle, proving the near approach which it made to the Sun when in perihelion, within about half a million of miles of his centre, or twice the Moon's distance from us, so that its distance from his surface must have been very small. The result of these calculations was that the comet was moving in a long elliptic orbit, requiring several centuries to traverse; and Newton

and Halley thought that it might be identical with large comets seen in A.D. 1106, A.D. 531, and B.C. 44 (the last was the one seen shortly after the death of Julius Cæsar). But, as already remarked, the only reason for this conjecture was that the appearances of these fine comets were all separated by intervals of about 575 years. More recent calculations show that the period of the comet of 1680 amounted to much more than this—probably to some thousands of years. It is impossible to determine this accurately from observations made at one appearance; still the calculations are sufficient to prove that it is exceedingly unlikely that this comet was in the neighbourhood of the Earth within any historic date before 1680.

The next remarkable comet appeared in the summer of 1682, and was very extensively observed, by Flamsteed at Greenwich, by Halley (then on the continent) and Cassini at Paris, and by many others. It was some years after this that Halley undertook, as stated above, the labour of calculating the elements of all the comets which had been sufficiently observed to enable him to do so. The results were published in the *Philosophical Transactions* for 1705. He remarks

that the earliest of which really accurate observations were made was one which appeared in 1472, and was observed by John Müller (commonly called Regiomontanus, the Latinised name of his birthplace, which was Königsberg in Franconia) at the observatory, the first in Europe, recently founded for him by his friend Bernhard Walther at Nuremberg. A comparison of the elements of all the comets thus computed by Halley showed that those which appeared in the years 1531, 1607, and 1682, were moving in orbits very similar to each other. Hence he was led to conclude that they were in fact successive appearances of the same comet, revolving round the sun in a period of about 75 or 76 years; and he was the more confirmed in this by the fact that a remarkable comet was recorded to have appeared in the year 1456, which was 75 years before 1531. He concluded by confidently predicting that it would reappear in the year 1758. It did so return, being first seen on Christmas Day in that year by a Saxon farmer and amateur astronomer, named Palitzsch, at Prohlis near Dresden. Subsequent calculations led the late Dr. Hind to identify it with great probability with comets seen at many intervals

of 76 years before 1456; the first being so far back as B.C. 12, in the reign of the Emperor Augustus, and the second in A.D. 66, shortly before the Jewish war broke out which ended in the destruction of Jerusalem by Titus. It was also very conspicuous in the year A.D. 531 (in the reign of Justinian) and in the spring of A.D. 1066, the year of the Norman Conquest in England. When Halley's prediction was fulfilled (16 years after his death) by the reappearance of the comet of 1682 in 1758, it was called after his name, and has ever since borne the designation of Halley's comet. It appeared again in August 1835, passing its perihelion on November 16, and may be expected once more in 1910.

A magnificent comet appeared in the year 1743, which was first seen by Klinkenberg, at Haarlem, on the 9th of December, and passed its perihelion on the 1st of March, 1744; after this, the only very fine one seen in that century was one which appeared about the time of the birth of Napoleon I., in 1769; it was first seen by Messier, on August 8th. The latter has been calculated to have a period of about 2000 years; the former, that of 1744, one much longer still, amounting perhaps to more than 100,000 years. The finest comets

of the present century were those of 1811, 1858, and 1861. The first of these was discovered by Flaugergues at Viviers, March 26, and remained visible until the month of August, 1812; its period was calculated to be about 3000 years. The second was first seen by Donati, at Florence, on the 2nd of June, 1858, and made a magnificent appearance in the autumn of that year; its period is probably nearly 2000 years in length. The third was discovered by Mr. Tebbutt, at Windsor in New South Wales, on the 13th of May, 1861, and continued visible until the summer of the following year; its period is shorter than those of the two preceding, and determined to be about 419 years. It was calculated that the Earth passed through part of the tail of this last about the end of June, 1861.

When Halley made his prediction of the return of the comet of 1682, he also pointed out a similarity between the elements of the orbits of comets observed in the years 1532 and 1661, which led him to conjecture that they might be identical; but he thought too little reliance could be placed upon the accuracy of the observations made of the former to feel sure of this, or to expect that the comet would actually return. In later times Maske-

lyne expressed more strongly the view that the comet would return in 1789, but Halley's doubt was justified by the event. It was not until seventy years after his death that another successful prediction of the return of a comet was made, and this was in reference to one which appeared in 1812, being discovered by Pons, at Marseilles, on the 20th of July in that year, and passed its perihelion on the 15th of the following September, the very day on which the conflagration broke out at Moscow, and compelled the French army under Napoleon to retreat from that city. The comet became visible, but not conspicuous, to the naked eye. In 1816, Encke, then assistant at the Seeberg Observatory (afterwards removed to Gotha), made a complete investigation of its motions from all available observations, and concluded that it was moving round the Sun in an elliptical orbit, the period of which was about 71 years, a little shorter than that of Halley's comet. As there was no record of any previous appearance of this comet (easily accounted for by the comparative feebleness of its light), the calculated length of period was somewhat uncertain, being dependent upon observations made during so small a

portion of the whole orbit as was traversed in about ten weeks. Nevertheless it turned out to be nearly correct; the comet was rediscovered by Mr. Brooks, at Phelps, New York, on the 1st of September, 1883, and passed its perihelion on the 25th of January, 1884.

In the third year after Pons discovered the comet of 1812, Olbers, of Bremen, discovered, on the 6th of March, 1815 (whilst Napoleon was marching to Paris for a restored but short-lived empire), a small comet which scarcely became visible without telescopic aid. It passed its perihelion on the 26th of April, and was observed until the autumn. Bessel, the illustrious astronomer of Königsberg, undertook the calculation of its orbit, which he found to be elliptical, with a period of about the same length as that of the comet of 1812. Allowing for the effects of planetary perturbations, he predicted that it would return early in 1887. Mr. Brooks was again the first to see the returned comet, which he detected on the 24th of August, 1887, and it passed its perihelion on that occasion on the 8th of the following October.

It need hardly be stated that both Encke and Bessel were, in these last two cases, circumstanced like Halley in reference to the

comet of 1682, and did not live to see the success of their own predictions, the verification of which was left for others. But we are now to speak of comets of much shorter periods, so that they have returned repeatedly within the lives of the same persons. Of these the most remarkable, and that of the shortest period of all, is one to which the name of Encke is always attached, from his having been the first to calculate its orbit and predict its return. This he did on the occasion of its appearance in 1818, when it was first seen by the indefatigable comet observer and discoverer, Pons, on the 26th of November, and passed its perihelion on the 27th of January, 1819. Encke soon afterwards took in hand the investigation of its motions, and proved that it had an elliptic orbit with period of only about $3\frac{1}{3}$ years. Hence he predicted its return in the summer of 1822, and this was duly verified, the comet being detected by Rümker at Sir Thomas Brisbane's observatory, then recently established (but not now existing) at Paramatta, New South Wales, on the 2nd of June, it not being visible in the northern hemisphere at that return. After the recognition of its period, it was found that Encke's comet had been observed on three separate

occasions before it was seen by Pons in 1818; in 1786, 1795, and 1805, when it was discovered by Méchain, Miss Caroline Herschel, and Thulis respectively. Even in 1795, the ellipticity of the orbit was suspected, and in 1805 Encke thought that the period was somewhat more than 12 years. It was, as we have said, about that interval afterwards that it was seen again, and that Encke succeeded in determining its true length of period. The comet has returned, and been observed at every succeeding calculated return according to prediction. It was last in perihelion on the 4th of February, 1895, and another return will be due in the spring of 1898. This comet has on several occasions been just visible to the naked eye, the last of which was in January 1895.

We now come to a very remarkable comet which, after returning several times, ceased to do so, and must be looked upon in the light of a departed friend. First discovered by Montaigne, at Limoges, in 1772, it was detected again by Pons in 1805. Although even then the identity of the objects seen on those two occasions was suspected, the observations were not sufficient to determine the true length of period, and the comet was not

seen again until 1826, when it was discovered, as if a new one, by an Austrian officer and amateur astronomer named Biela, at Josephstadt in Bohemia, on the 27th of February. Its orbit (calculated by Biela himself, and more accurately by Gambart) showed not only its identity with the preceding, but that the period amounted to only about six and a half years. It was observed again in the autumn of 1832, but not seen at the next return in 1839, in consequence of its unfavourable position on that occasion. Towards the end of 1845 it once more appeared, but no longer as a single comet. It had separated into two of unequal brightness, subsequent calculation showing that this most probably occurred in the year 1844. Both comets returned, somewhat farther apart, in 1852, but since then neither has been seen with certainty. The position would have been unfavourable in 1859, as in 1839, but in 1866 great disappointment was felt at its non-appearance. Shortly after this, it was pointed out that the Earth passes through the orbit of this comet about the end of November every year, and that a number of meteors were often seen at that season. A grand meteoric display was witnessed on the 27th of November, 1872, and

it was at once suspected that this might have some connexion with the lost comet, although the latter would have been due in that part of its orbit several weeks before. The late Mr. Pogson, then the astronomer at Madras, being requested by telegram, turned a telescope to the quarter of the heavens opposite to that from which the meteors had appeared to radiate, and saw a cometary body in that direction, the motion, however, of which did not agree with what Biela's comet might have been expected to have. Another magnificent display of meteors was seen on the same day in 1885, thirteen years after the former; and a fine one (probably connected) somewhat earlier (November 23) in 1892.

But we must go back to comets. A faint one was discovered by Pons on the 12th of June, 1819, and Encke's investigations showed that it was moving in a short ellipse with a period of about 5½ years. It was not, however, seen again until 1858, when it was rediscovered as a new comet at Bonn, by Prof. Winnecke, who, after he had determined its orbit, noticed its identity with the discovery made by Pons nearly forty years previously. Hence it is usually called Winnecke's comet. It was observed again in 1869 and 1875, but

not in 1863 or 1880, at which returns its positions were very unfavourable for observation. But it was observed at that which took place in 1886, and again in 1892, when it passed its perihelion in the month of June. The period having somewhat increased in length, the next return will be due in 1898.

A comet (also a faint one) discovered by M. Faye at Paris in November 1843, was found to be moving in a short elliptic orbit with a period of about $7\frac{1}{2}$ years, and has been observed at every subsequent return. It was in perihelion last on the 20th of August, 1888, and will be again in that position on the 19th of March in the present year (1896). At this return to visibility it was first seen by M. Javelle at Nice on the 26th of September, 1895, nearly six months before perihelion passage.

One fainter still was discovered by Brorsen (who died last year, 1895, at his native place on the island Alsen in the Baltic) at Kiel, in 1846. Its period is also about $5\frac{1}{2}$ years; it was, however, not seen in 1851 nor 1863, but was observed in 1857, 1868, 1873, and 1879. A return was again due in the autumn of 1884, and another in the spring of 1890; but at neither of these was the comet seen.

It is thought that some catastrophe has overtaken it; and it seems not improbable that a comet discovered by Mr. Denning on the 26th of March, 1894, was a portion of it.

The late Professor d'Arrest (afterwards of Copenhagen) discovered a very faint comet at Leipzig in 1851. This was ascertained by calculation to be moving in an ellipse, with a period of about 6½ years; and was observed again, but only in the southern hemisphere (at the Cape of Good Hope), in the winter of 1857. In 1864 it was not seen, being unfavourably placed; it was, however, observed at the returns of 1870 and 1877, but not in 1884, on which occasion there was felt to be small hope that it would become visible. It was, however, seen again in the autumn of 1890, after passing its perihelion on the 16th of September. The next return will be due early in the year 1897.

We pass on now to a comet, the period of which, though short, is more than double that of the preceding. It has in fact been observed on several occasions, but, being a faint object, these have not been consecutive appearances. The periodicity was discovered in 1858, when the comet was detected by Mr. Tuttle, at Cambridge, U.S., on the 4th of January.

The orbit was then calculated by Bruhns, who found that its period was about 13¾ years in length, and that the comet had been previously discovered by Méchain, at Paris, in 1790, after which it must have returned four times without having been noticed. It was, however, observed in the autumn of 1871, and again in 1885, when it passed its perihelion on the 11th of September. Another return will be due in the summer of 1899.

Two comets of short period were discovered by and named after the late M. Tempel, who became Director of the Arcetri Observatory near Florence, after the death of Donati in 1873, and died there in 1889. The first of these comets (the period of which is about 6 years) was found by him at Marseilles in 1867; it was observed at returns in 1873 and 1879, but not seen afterwards, though two returns have been due since; the last, according to the calculations of M. Gautier, of Geneva, not until 1892, in consequence of the perturbing effect of Jupiter upon the comet's orbit. Tempel's second periodical comet was discovered by him at the Brera Observatory, Milan, on the 3rd of July, 1873; its period is about 5½ years, and it was observed again in the autumn of 1878, but not seen at the returns calculated

to be due in 1883 and 1889, being unfavourably placed on those occasions. It was, however, re-detected in May 1894, after passing its perihelion on the 24th of April; another return will be due in 1899. Whilst still at Marseilles, Tempel had discovered another short-period comet in November 1869; but as its periodicity was not recognised until after it had been re-discovered by Professor Swift at the Warner Observatory, Rochester, New York, on the 11th of August, 1880, it is usual to call it Swift's comet. The period is only about 5½ years in duration, so that an unobserved return must have taken place in 1875. Being unfavourably placed also at the next return in 1886, it again escaped observation, but it was well observed at the last appearance in 1891, when it passed its perihelion in the month of November, and another return will be due in 1897.

A bright comet was discovered by Dr. Max Wolf, at Heidelberg, on the 17th of September, 1884, which was calculated to be moving in an elliptic orbit with a period of nearly 7 years, and as a return duly took place and was well observed in the autumn of 1891, another may be expected in 1898.

On the 26th of September, 1886, Mr. Finlay, at the Cape of Good Hope, discovered a comet which passed its perihelion on the 22nd of November, and was calculated to have a period of about 6½ years. A return duly took place in 1893, when the comet was re-discovered by Mr. Finlay himself on May 17, and passed its perihelion on June 16.

A passing reference must now be made to what was called De Vico's periodical comet. It was discovered by that astronomer at Rome on the 22nd of August, 1844, became visible to the naked eye, and was calculated to have a period of about 5½ years. The orbit being very similar to that of a comet discovered by La Hire, at Paris, in 1678, it was thought that the two were identical, the interval being almost exactly thirty times the calculated period. The comet was not seen again for more than fifty years, excepting that Goldschmidt obtained a single observation of one at Paris on the 16th of May, 1855, which may have been of this, though the identity cannot be proved. It was at one time thought that Finlay's comet (last mentioned) might be identical, the elements of the orbits being similar, but this conjecture proved to be untenable. A

small comet was discovered by Mr. E. Swift, in California, on the 20th of November, 1894, the orbit of which is very similar to that of De Vico. Later investigations by Dr. Schulhof and others have shown that it is in all probability identical with that body which must be subject to fluctuations of brightness. The attraction of Jupiter is increasing its perihelion distance, which considerably exceeds the distance of the Earth from the Sun. It was near that planet for some months in 1885 and 1886, and will approach it still more nearly in 1897.

Professor Barnard, of the Lick Observatory in California, discovered on the 16th of July, 1884, a faint comet which has been found to revolve in an elliptic orbit with a period of somewhat less than $5\frac{1}{2}$ years. It was unfavourably placed at the return due about the end of 1889, and was not seen either then or at the return subsequently due in the summer of 1895.

A comet, just visible for a few days to the naked eye, was discovered by Mr. E. Holmes, at Islington, on the 6th of November, 1892, and calculated to have an elliptic orbit with period of about $6\frac{3}{4}$ years. As the perihelion passage took place on the 20th of June

(nearly five months before discovery), a return will be due in the summer of 1899.

Very remarkable seems to have been the career of a comet, formerly called Lexell's lost comet, which was a truly unfortunate body from the way in which its motions were disturbed by the giant planet Jupiter. It was discovered by Messier, at Paris, on the 14th of June, 1770, being at the time very near the Earth, which it approached a few days afterwards within a distance of little more than seven times that of the Moon from us. Lexell calculated its orbit, and found that it was then moving in an ellipse with a period of about $5\frac{1}{2}$ years. But that had not long been the case, for in 1767 the comet had approached Jupiter within a distance of only about one-sixtieth part of the radius of the orbit of the planet, which subjected the comet so powerfully to the influence of his attracting mass that its orbit was completely changed. At the return next after the discovery, in 1776, its position was such that it was impossible for it to become visible; and in the year 1779 (when only about half another period had elapsed) the comet made another approach to Jupiter, much closer even than before, coming, indeed, nearer to the planet

than the distance of his fourth satellite; this again completely changed its orbit, making the period very much longer than that which Lexell's calculations determined it to be in 1770. In 1889, on the 6th of July, Mr. Brooks, of the Smith Observatory, Geneva, N.Y., discovered a comet which appeared to be moving in an ellipse of short period; Mr. S. C. Chandler, of Boston, U.S., showed that this body also made a very near approach to Jupiter in 1886, and suggested its identity with Lexell's comet of 1770, but the subsequent investigations of Dr. C. Lane Poor did not confirm this idea. Brooks's comet of 1889 was calculated to be moving in an ellipse with a period of nearly 7 years, so that it will probably come into perihelion again in the present year (1896). But another comet was discovered by Professor Swift in California on the 20th of August last year (1895), which Dr. Schulhof thinks was really identical with Lexell's long-lost comet. Its period is little more than 7 years, so that it will probably return in 1902, but unfortunately will then be unfavourably situated for observation.

No other short-period comet has yet been certainly known to have returned. One, indeed, discovered by Edward Pigott, in

November 1783, was calculated to be moving in an ellipse, with a period of about five years ; but this was uncertain, some thinking the period amounted to ten years in length, and at any rate the comet does not seem to have been seen either before or since. And mention must be made of one which appeared little more than twelve years ago, being discovered by Mr. W. F. Denning, of Bishopston, near Bristol, on the 4th of October, 1881. The period was determined to be about nine years, but the comet has not been seen since, probably owing partly to the unfavourable position in which it was placed in 1890 ; it is likely, also, that its path has been perturbed by the attraction of the planet Jupiter.

A few words are here desirable respecting comets which have been surmised to have appeared on more than one occasion, though this has by no means been proved.

A splendid comet was seen in 1264 (the year of the battle of Lewes) and another in the year 1556 (about the time of the abdication of the Emperor Charles V.). So far as it has been possible to determine the orbits of these comets from the descriptions given of their courses, they appear to have been very similar to each other. This was first pointed

out by Dunthorne, in 1751, and attention was long afterwards specially called to it by Hind, whose investigations led him to think it extremely probable that these were two consecutive appearances of the same comet, which was revolving in a long period of nearly three hundred years. It was shown that the effects of planetary perturbation would delay another return, and on the whole it was thought most likely that the comet would be seen again about the year 1860. Neither then, however, nor at any time since, has it put in an appearance. Either, therefore, the comets of 1264 or 1556 were not identical (and orbits deduced from descriptions of courses before accurate observations were made must be very uncertain), or possibly some unknown perturbing influence may have acted upon it in the distant regions to which it travelled between those years. It may here be remarked that, whilst Halley's comet, when in aphelion, is at about the same distance from the Sun as Neptune, a comet with a period of three hundred years would pass far beyond the orbit of that planet.

A comet observed by Tycho Brahé and others in 1596, appears to have orbital elements similar to those of the third comet of

1845; and the two may be identical, with a period of about two hundred and fifty years. The same remark may be made with regard to a comet discovered by Mr. Brooks on the 22nd of November last year (1895), the orbit of which is very similar to that of a comet seen in 1652.

Allusion must also here be made to a great comet respecting the motions of which there was much discussion in the autumn of 1882, and on the question whether it had any connexion with the fine comets of 1843 and 1880, or these with each other, or with any seen in bygone centuries. It is an undoubted fact that the elements of the orbits of the comets of 1843, 1880, and 1882, were all very similar to each other; and it is probable that those of a comet seen in 1668, which was very imperfectly observed, were also similar. All made, when in perihelion, remarkably close approaches to the Sun, coming within a distance of 700,000 miles of his centre, or about 300,000 miles of his surface. Hence it was suggested that the tremendous attractive force exerted by the Sun upon the comet at so small a distance, might greatly shorten the period at each return, and lead before long to the comet's absorption into the Sun, pro-

ducing an outburst of solar heat of enormous and incalculable amount. On the other hand, similarity of orbit in two or more bodies does not prove that these bodies are identical, since it is quite possible that there may be two or more comets moving along the same orbit at considerable distances from each other. Moreover, the best determinations of the orbit in which the comet of 1882 was actually moving agree in assigning about 750 years as the length of its period. It is probable, therefore, that all these comets are following each other along the same orbit, which it takes about that time to complete for each; and another member of the same family was discovered on the 18th of January, 1887, which was conspicuous for a few days in the southern hemisphere, but never visible in the northern. It should be remembered, with regard to the comet of 1668, that the observations made of it were too few and too uncertain to enable astronomers to draw any decided conclusion from them as to its true path. The tail only was visible in Europe; and such knowledge of the comet's orbit as we possess is chiefly derived from a map of its course in the heavens, laid down from some very rough observations made in the

East Indies, extending over an interval of less than a fortnight in the month of March; from this it appears probable that the comet is moving in the same orbit as those of 1843, 1880, 1882, and 1887.

We must next speak of two comets which have become remarkable owing to very unexpected circumstances respecting them, which have been recognised since their discovery. The first of these appeared in the year 1862, when it was discovered by Prof. Swift (now Director of the Lowe Observatory on Echo Mountain, in Southern California) at Marathon, N.Y., on the 15th of July, and a few days afterwards by several others. During part of August (it was in perihelion on the 23rd of that month) and September it was visible to the naked eye, with a tail at one time of about 25 degrees in length. The comet's orbit was computed by the late Dr. Oppolzer, of Vienna, who found it to be elliptic, with a period (so far as could be determined from the short portion of it during which the comet was under observation) of somewhat more than 120 years. The other comet of which we are now speaking was discovered by Tempel, at Marseilles, on the 19th of December, 1865; it passed its perihelion

on the 11th of January, 1866, and during the whole time it was visible (about four weeks) remained telescopic. Calculation showed that it was moving in an elliptic orbit, the period of which did not much exceed 33 years. Now it was about this time that great discoveries were made respecting meteoroids, as they are called, that is, streams of meteors which are now known to revolve in long elliptic orbits round the Sun. It had long been known that great numbers of meteors were often seen in the middle of November and in the second week in August; but it was not till 1864 that Prof. H. A. Newton, of New Haven, Connecticut, U.S., pointed out the regularity of the appearances of the former in especial abundance at intervals of about thirty-three years, and suggested the cause. The fact, proved by his exhaustive examination of the available records (reaching back to A.D. 902), that the display of mid-November meteors took place slightly later at each return, and that the earliest accounts showed that many centuries ago it occurred in October, enabled the late Prof. Adams, of Cambridge, to investigate fully the motions of the stream, proving that it revolved round the sun in about 33¼ years, and

that its orbit carried it very near the Earth's at the perihelion or point of the former which is nearest the Sun, so that we pass through this orbit each November, though a brilliant display is seen only in those years in which the Earth traverses the thick part of the stream. The fact was now noticed that the orbit of this meteoric stream is almost identical with that of the small comet discovered by Tempel in December 1865. Prior to this, however, Prof. Schiaparelli, of Milan, had detected a similar coincidence between the orbit of the meteors of the second week in August and the bright comet discovered by Swift and others in July 1862, which also was near the Earth's orbit when in perihelion. It would appear that these August meteors (which are called Perseids, because they appear to radiate from the constellation Perseus) are much more uniformly distributed along their orbit than the mid-November meteors (called Leonids because radiating from the constellation Leo), the consequence of which is that we see a considerable number of them at every return, though the display is always far inferior to that of the mid-November stream, when we are passing through the part where its meteors are most thickly congregated.

The nature of the connexion between the meteoric streams and the comets moving in the same orbits is by no means fully understood. Neither of the comets in question has been seen at more than one appearance. Great interest will be felt in the return of Tempel's, which will be due in 1899, earlier in the year than November, when we shall cross its orbit and probably encounter a meteoric display comparable to those of 1833 and 1866. A return of the August-meteor comet of 1862 is not likely to take place until about the year 1985.

Another remarkable circumstance must be pointed out with regard to the comet of 1865, or rather of 1866, for it is usual to number them, not according to the date of discovery, but of perihelion passage. All the short-period comets move with what is called direct motion, that is, roughly speaking, in the same direction as that of the planets round the Sun, from west to east. Those of long period are some of them direct and some retrograde. Now the comet in question is retrograde and is the comet of shortest period which moves in that manner. When nearest the Sun it is, as we have seen, about the same distance from him as the Earth; when farthest from him, or

in aphelion, it is at about the same distance as the planet Uranus, the satellites of which also move in a retrograde direction. The three comets which have periods of somewhat more than seventy years (Halley's and those of 1812 and 1815, previously mentioned) recede from the Sun when in aphelion somewhat farther than the planet Neptune; Halley's (which reaches farthest of the three) is retrograde in its motion, the two others direct. Most of the short-period comets revolve in periods of from five to seven years, and attain at aphelion a distance from the Sun about equal to that of Jupiter; Encke's, however, revolving in $3\frac{1}{3}$ years, falls considerably short of this, and Tuttle's, which requires $13\frac{3}{4}$ years to complete its period, exceeds when in aphelion the distance of Saturn by about that of the Earth.

It may be of interest here to mention the singular way in which a comet was "caught" into view, in consequence of passing near the Sun whilst the latter was totally eclipsed. This was on the 17th of May, 1882, when a photograph of the eclipse, taken by Dr. Schuster in Egypt, clearly depicted the stranger in the outer rays of the corona. As the comet was not visible, either before or afterwards, its motion

must have been extremely rapid, and it owed its momentary detection to the obscuration of the Sun's light by the Moon when the photograph was taken. Nothing of course is known of the orbit of this comet, which was called "Tewfik," after the then Khedive of Egypt.

Another, much fainter and more difficult to recognise, was photographed in the corona during the total eclipse of April 16, 1893.

Perhaps a few words may be allowed, in conclusion, on the composition of comets. It has long been evident that whatever may be the matter of which they consist, it must be of extreme rarity and feeble condensation, as shown by the absolutely imperceptible effect produced by it upon the motions of planets or other bodies which have been approached by comets. The most remarkable instance of this was in the case of the so-called Lexell's comet which (as mentioned above) moved into the midst of Jupiter's system, and approached the planet more nearly than the most distant of his satellites. Many other comets have come within a comparatively small distance of Jupiter, and Encke's has on several occasions made close approaches to Mercury, whilst there are cases in which comets have passed the Earth at

less than a quarter of the distance to which the nearest planet ever comes. Yet whilst the comets have severely felt the effect of these *rencontres*, in the alteration of their paths by the planetary attraction, the planets and satellites themselves have pursued the even tenor of their way, undisturbed in their respective orbits by the erratic but impotent comets. The nature of the connexion between them and meteoric streams, is, as before remarked, unknown, and it is quite possible that the observed identity of orbit in some cases, instead of showing community of composition, simply arises from the comet having been caught and kept "in durance vile" by the meteors.

But another circumstance showed how exceedingly diffused must be the matter of which comets consist, viz., that they are so transparent that stars have been seen through their most central parts without suffering any diminution of light, nor was any refraction manifested by the slightest alteration in the apparent position of the stars so observed. This led Sir John Herschel to use the expression, "the filmy and almost spiritual texture of a comet," but it must be borne in mind that it does not follow because the mean density of one of these bodies is excessively

small, that that of its constituent particles is so too, only that otherwise these must be very small, and widely separated from each other.

But as regards the actual composition of comets, although the fact that their light showed traces of polarisation proved that part at least of it was reflected sunlight, nothing further was known until the introduction of spectrum analysis and its application to comets. This was first done in 1864, by the late Prof. Donati, of Florence, the discoverer of the great comet of 1858, and was afterwards vigorously taken up by our distinguished countryman Dr. Huggins, by Dr. Vogel of Potsdam, and others. The result was, as beforehand seemed probable, that the spectrum was twofold; one, which was very faint, evidently due to reflected sunlight, and another discontinuous with bright bands, indicating the presence of gaseous matter in a state of incandescence. To what its luminosity is due cannot be stated with certainty, but there can be little doubt that electricity is concerned in this, and plays a large part in cometary phenomena generally. The comparison of the banded spectrum in comets with those of terrestrial substances shows that the gaseous or nebular portion of comets is to a great extent hydrocarbonic in its composition; but those

comets which have approached the Sun more closely than others have exhibited in their spectra, when near him, other lines, known to be produced by some metals when in a state of vapour.

Our allotted space forbids us to treat this interesting subject here at greater length, but enough has been said to indicate how the continuous progress of science in the past leads us to anticipate yet larger accessions to our knowledge in the future, and in particular we hope by this little treatise to quicken the interest felt in future appearances of comets.

The following is a list of the dates in order of the next returns of the comets which may with some confidence be expected to reappear :—

1896, Spring*—Faye's comet (period $7\frac{1}{2}$ years). Also, in spring or summer—Brooks's comet (period, 7 years).

1897, Spring—D'Arrest's comet (period $6\frac{1}{2}$ years). Also, about the same time—Swift's comet (period, $5\frac{1}{2}$ years).

1898, Spring—Encke's comet (period, $3\frac{1}{3}$ years). Summer—Winnecke's comet (period, $5\frac{1}{2}$ years). Also, in autumn—Wolf's comet (period, nearly 7 years).

* Perihelion passage in March: comet was observed in previous autumn (1895).

1899, Spring—The comet of 1866, connected with mid-November meteors (period, $33\frac{1}{3}$ years). Also, in summer of same year—Tuttle's comet (period, $13\frac{3}{4}$ years), Tempel's second periodical comet (period, $5\frac{1}{4}$ years), and Holmes's comet (period, nearly 7 years). And, in winter—Finlay's comet (period, $6\frac{1}{2}$ years).

1900, Winter—Barnard's comet (period, $5\frac{1}{2}$ years).

1903, Autumn—Faye's comet (period $7\frac{1}{2}$ years).

1910, Summer—Halley's comet (period, about $75\frac{1}{2}$ years).

1955, Spring—The comet discovered by Pons in 1812 and re-detected by Brooks in 1883 (period, about 71 years).

1960, Spring—The comet discovered by Olbers in 1815 and re-detected by Brooks in 1887 (period, about $72\frac{1}{2}$ years).

1985—The third comet of 1862, connected with August meteors (period, probably about 123 years).

We have not included in the above list those comets of short period which have been seen at only one appearance, and then were visible during so short a time that the duration of their periods could not be determined with accuracy.

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